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TITLE: Changes of Ventilator Generated Volume and Pressure under Simulated Cabin Pressure Profiles of Military Aircraft C160 Transall

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Changes of Ventilator Generated Volume and Pressure under Simulated Cabin Pressure Profiles of Military Aircraft C160 Transall

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Introduction :

Pulmonary traumata and special intensive care therapies often lead to a respirator treatment.
After stabilisation of the patient vital functions in the medical installations of the operation area the respirator-treatment has to be continued during the air-transport for repatriation.
Patient and ventilation equipment are exposed to certain influences caused by the air-transport. Originaly respirators are built for the use on the ground (air-pressure 1013 mbar) with only slight changes (+/- 20 mbar) in air-pressure.
In military Medevac-airplanes there are significant and quick changes (de- and increases) of the pressure cabin in cruising altitude and in tactical flight manouvers.
Aim of this study was to examine the influence of cabin pressure on important parameters of ventilation using different transport ventilators. Simulating cabin-pressure conditions, differences in the applied tidal volume and PEEP to a preset value were to be determined.
The results of this study may help to develop guidelines to reduce the risk of the treatment of ventilated patients during air-transport.

Method :

The experiment was based on the continuous recording of pressure changes in a lung-model with known compliance. After measuring and recording on-line, volumes applied by the respirator were calculated and PEEP-levels were read.
The experiment consisted of the respirators Oxylog 2000 and EVITA 4 (Dräger Co., GE), their tubing system and a lung-model (Isolung: glasballoon 54 l filled with 10 kg copperwool to guaranty isothermic condition changes)
The pressure differences between decompression-chamber and isolung, the pressure inside the decompression-chamber, the temperature in the lung-model and in the decompression chamber were measured by gauges.
To verify the influence of environmental pressure-conditions to the respirator functions in a plane (C160 Transall) the experiment was performed in the decompression-chamber of the German Air Force Institute of Aerospacemedicine in Fürstenfeldbruck.

After defining ventilation modes and parameters the apparatus were exposed to simulated cruising level (max. 10.000 ft), emergency decent (-6000 ft/min) and rapid decompression.
The arrangement of the test allowed pressure-changes which correspond to altitude differences of 14.000 ft in the EVITA 4 and of 8.ooo ft. in the Oxylog 2000. Immediately after the emergency descent of 6000 ft/min was simulated.
Inside the lung-model pressure changes up to 40 mbar could be measured.

Results :

Table 1 shows the applied tidal volume during minimal cabin pressure (10.000 ft). The Oxylog 2000 increases the tidal volume by 50 % to 1200 ml (preset value 800 ml) in IPPV mode.
The EVITA 4 in IPPV mode generates a plus of 22 % to a preset tidal volume of 800ml which results in a value of 980 ml. In the pressure-controlled BIPAP Mode, with preset values of p max=20 mbar and PEEP of 5 mbar a tidal volume of 1080 ml is generated (+38 %).

Paper presented at the RTO HFM Symposium on "Operational Medical Issues in Hypo- and Hyperbaric Conditions", held in Toronto, Canada, 16-19 October 2000, and published in RTO MP-062.

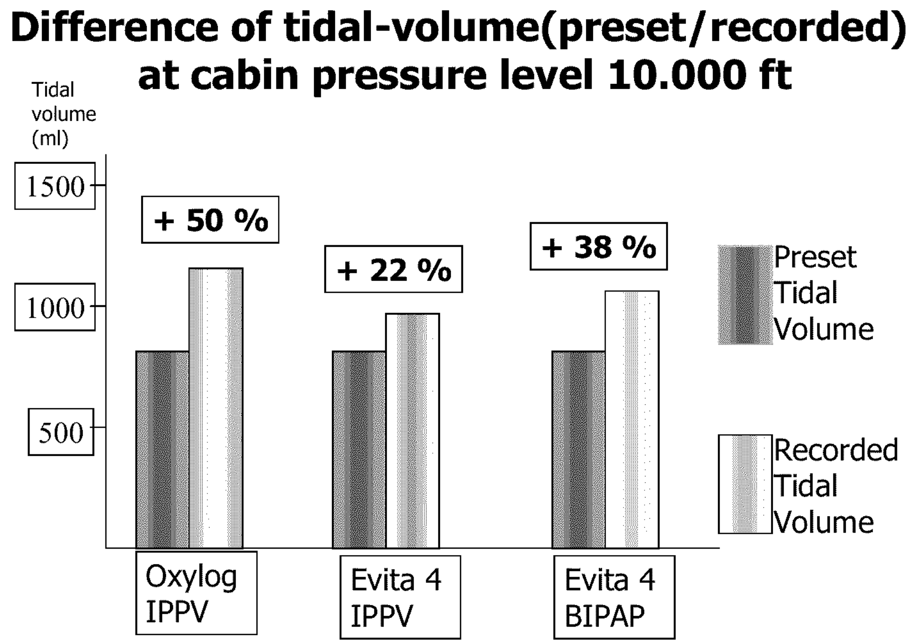
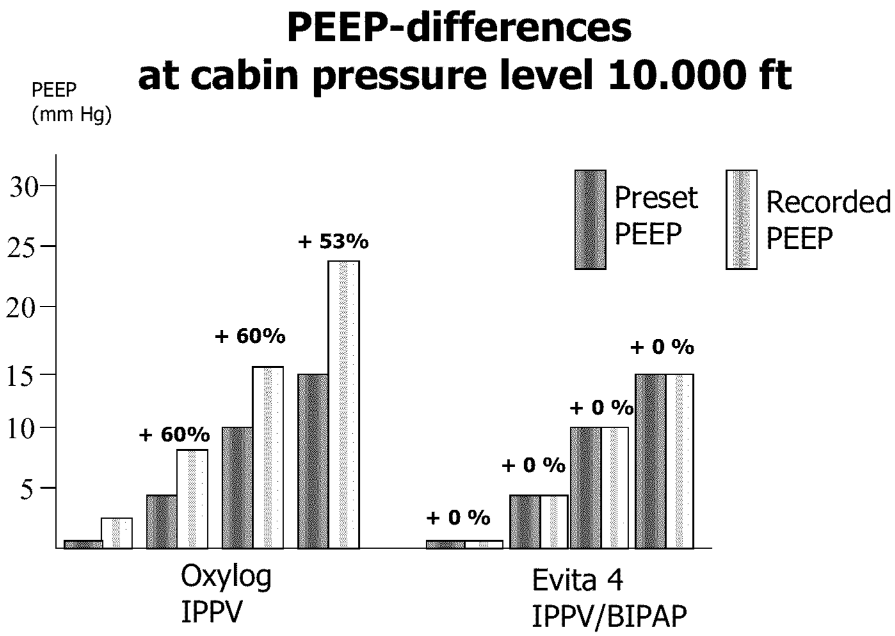


Table 1

To the beginning of climbing the Oxylog reacts with an alternation of the tidal volume by + 160 ml. Starting the descent the tidal volume is once elevated by +280 ml compared to the previous breathing cycle. Immediatley after reaching ground level-pressure the applied tidal volume falls by –80 ml in comparison to the earlier breathing cycle. Between the cycles there are variations up to 60 ml.
Using the EVITA 4 in IPPV mode the variations during climb amount to 20 ml. At the beginning and during the descent differences up to 150 ml occur.
In BIPAP ventilation the differences remain smaller than 10 ml, only initially of descent there is a tidal volume peak of +150 ml.
The measured PEEP-values show obvious differences (s. Table 2) .
The registred shift during the whole test using the Oxylog 2000 was +2,5 mbar (preset 0 mbar). Picture 2 shows the PEEP levels in cabin-pressure 10.000 ft, differences up to 50 % can be seen.
The EVITA 4 creates both in volume as in pressure-controlled ventilation-mode stable values on preset level.

Table 2



Emergency descent :

Oxylog 2000 :
Calculated 1200 ml tidal volume at 10.000 ft (preset 800 ml) are decreased by 50 % to 600 ml initially in descent. During the following 55 sec the tidal volume varies between 600-700-ml, than a continuously increase occurs. Approximately 20 sec. after reaching ground level-pressure constant tidal volume is produced. Starting the emergency descent PEEP of 8 mbar (preset 5mbar) immediately falls to 0 mbar, then 1 mbar is registered constantly. When reaching original tidal volume the Oxylog 2000 produces stable value of 7 mbar (Table 3).

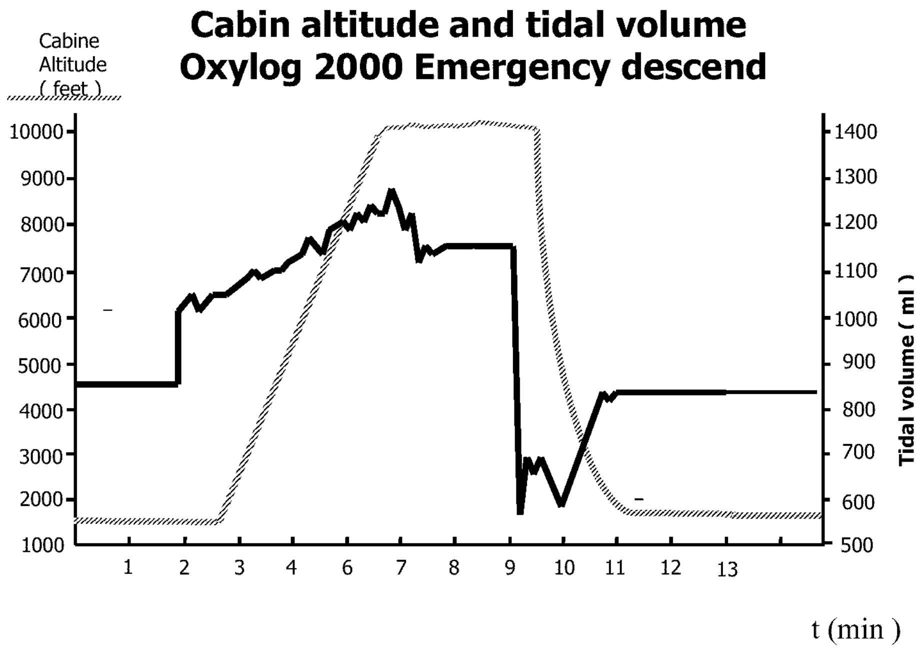


Table 3

Evita 4/IPPV: Calculated 920 ml tidal volume (preset 800 ml) was reduced by 250 ml at the beginning of emergency descent, then varies from 350 ml to 800 ml and reaches and maintains a constant tidal volume directly on ground. The chosen PEEP of 0 mbar decreases to –1 mbar but shows starting value towards the end of the test (Table 4).

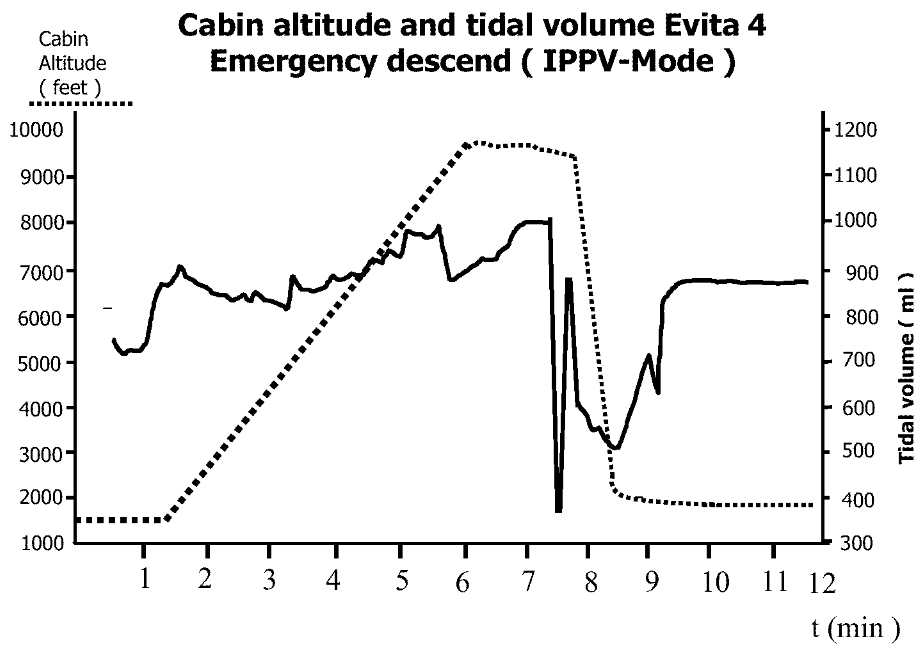


Table 4

Evita 4/BIPAP: When cabin pressure rises, the applied plateau pressure of 20 mbar falls to 8 mbar, the correspond tidal volume decreases from 1060 ml to 280 ml (-73,6%). 25 sec after the the beginning of the emergency descent the original tidal volume calculated increase and stay stable during the course. PEEP decreases from 5 mbar (preset 5mbar) to 4 mbar .

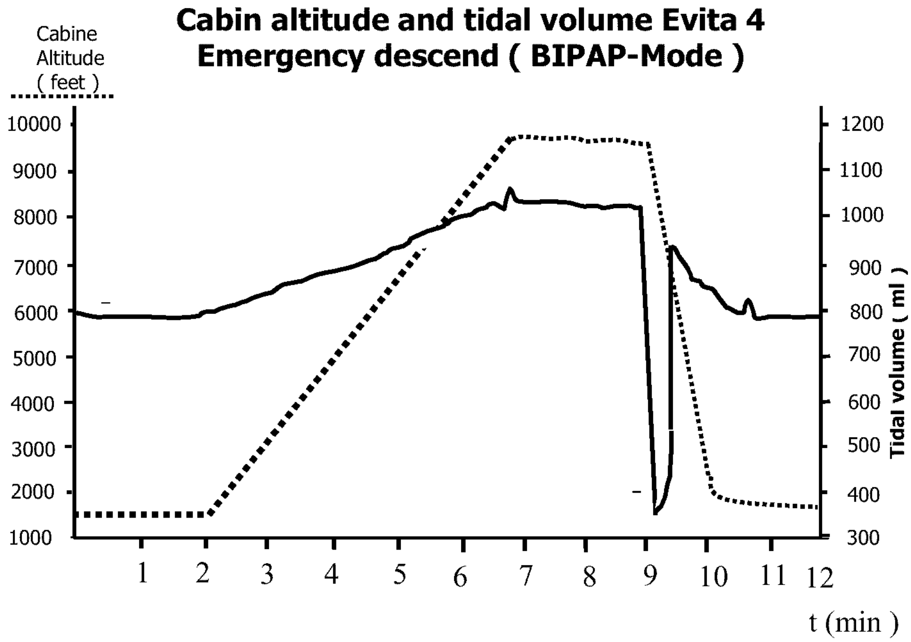


Table 5

Rapid decompression

The results of tidal-volume during rapid-decompression-tests are – due to unisothermic conditions of pressure-changes - of limited validity.

Oxylog 2000:

At the beginning of rapid decompression the system pressure increases rapidly up to 40 mbar registered.

In comparison to the results of emergency descend the tidal volume decreases from 1150 ml to 900 ml ;

varitions from 950 to 600 ml ocured; after reaching ground level pressure a contineous tidal volume of 800 ml is generated.(Table 6)

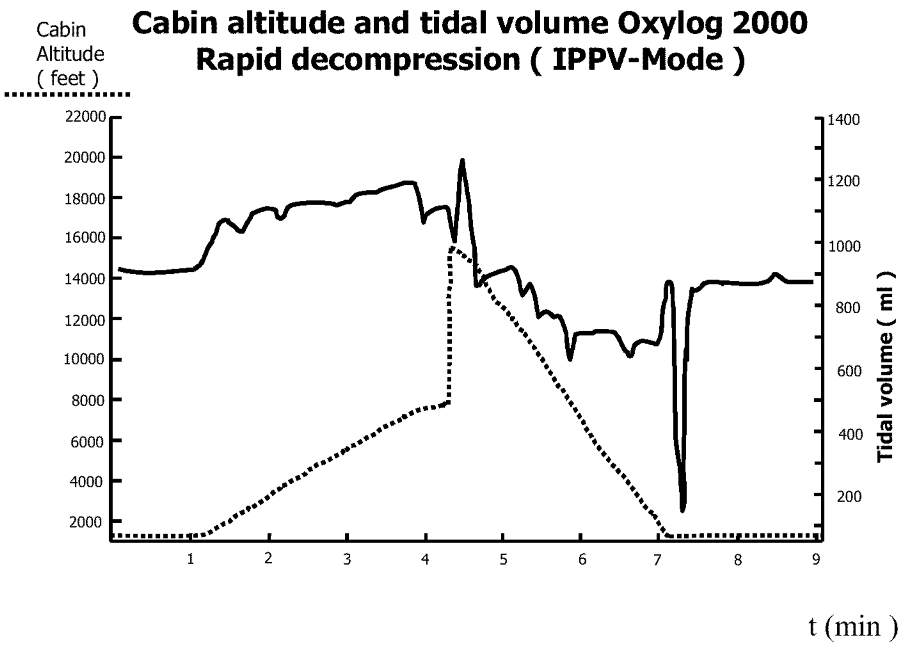


Table 6

Evita 4 (IPPV):
Like the Oxylog performance initialy the system pressure decreases up to measured 40 mbar. Then the tidal volume falls from 950 ml to 500 ml. In the next 30 sec the tidal volume increases to 800 ml; till the end of the cabin pressure chances the tidal volume decreases to 550 ml. After reaching ground level pressure a tidal volume of 840 ml is generated (Table 7).

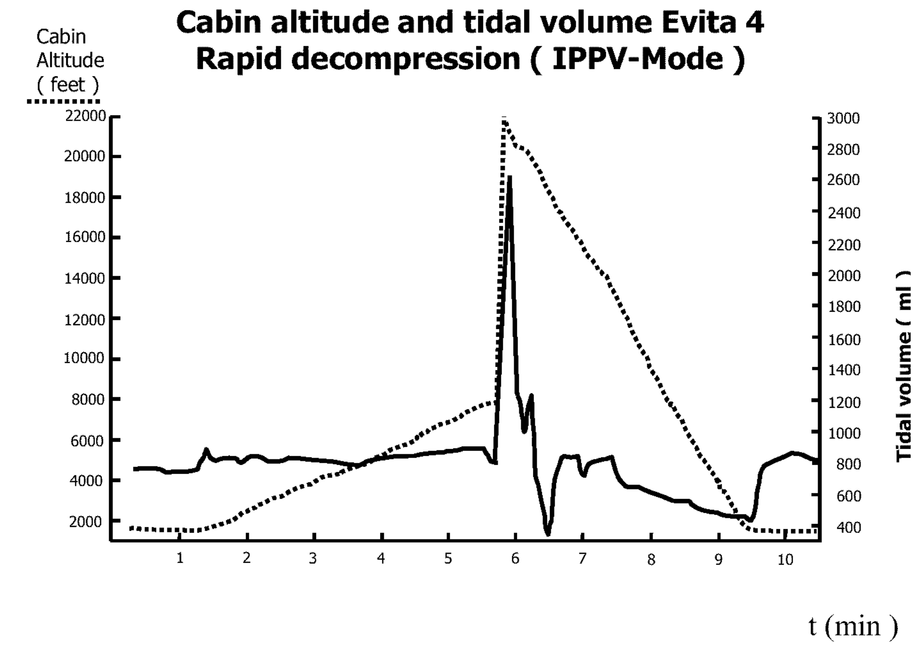


Table 7

Conclusions

The respirators tested under simulated cabin-pressure-conditions of the military airplane C160 Oxylog 2000 and Evita 4 basically proved that they work securely.
The surrounding pressure has a considerable impact on essential ventilation-parameters.

It was shown that both devices – to a different extent - delivered higher tidal volume to the lung-model when exposed to simulated cabin pressure. Possible clinically relevant consequences are hyperventilation, shifts in acid-base-balance and barotrauma.
The Oxylog 2000 in comparison shows high variations in PEEP. The variations are of clinical relevance that exceed a plus of 50 % of the preset value. Stress of the cardio-vasculary system caused by intrathoracic fluid shifts, of the downstream cerebrovascular system with consecutive increase in intracranial pressure, of the alveolar structure and the surfactant-layer are likely.

The pressure – controlled ventilation mode BIPAP of the Evita4 offers obvious advantages compared to the IPPV mode – even though higher change in the tidal volume occurs.
Reasons herefor are the constant increase of the tidal volume during climb and descent, the neglectable variations in applied volume between the breathing cycles and the faster generation of a sufficient tidal volume in case of emergency descent.

If the apnoic oxygenation of the patient with high oxygen-flow may be an easier alternative to the controlled ventilation in case of an emergency descent has to be examined.

The rapid loss of cabin-pressure represents a threatening situation for t the whole crew and especially for the ventilated patient.There was no damage to the tested equipment detected and the devices worked without interference after ending the pressure variations.
Because of the massive increase of pressure in the system patient-lung – ventilation tubes barotrauma of the pulmonary system are possible.
Devices like the Evita 4 surely offer a higher patient security in this case, as the expiratory flow and fast switching valves allow a quicker decrease of the pressure in the respiratory system.
Prophylactic precautions to prevent damage of the lungs by the rapid decompression can hardly be taken as of the peracute nature (and the unpredictable occurrence) of this situation.

The air-transport of ventilated patients - especially in military operation conditions - is always full of risks even when using modern respirators. To guaranty the highest patient security the following checklist should be looked at before the transport:

- controlling of breathing tube position, respirator function and patient – respirator interaction before engine noise sets in
- sufficient sedation and analgesia, generous indication for muscular relaxation (prophylaxis of coughing)
- insertion of a stomach tube
- application of nasal decongestants (pain when cabin pressure increases during descend)
- setting of pressure limitations
- general use of (minmal) PEEP to prevent negative airway pressures during descent
- reduction of PEEP during climb when using Oxylog 2000
- cuff pressure measurement
- decompression of pneumothoraces
- capnography / pulsoxymetry for monitoring
- BGA control to uncover hyperventilation